

# THE CHEM PLANT

*The crew is versatile, processing various types of fuel at different times...*

—Phillips Petroleum Company—

It was 1950. Chemist Don Reid and others at Oak Ridge were nearing the end of four years' work to invent and design a pilot chemical processing plant for MTR fuel. They had found a work place in what Reid called "a little bit of a shed" on a hill overlooking the Oak Ridge plant and next door to the shed commandeered by Captain Rickover for his early studies in naval nuclear propulsion. Reid recalled how they got started.

*After looking around the laboratory and other areas in Oak Ridge...and seeing what was available in the way of material, it was decided to use old bismuth-phosphate plant equipment stored in the field west of the laboratory... We found some old...columbium-stabilized stainless-steel plates out in the field and this was to be used for the dissolver. This was taken by R.M. "Murph" Jones, later of MTR Engineering, to Nooter Engineering Works in St. Louis, a fabricator for Monsanto. Jones followed the fabrication of this special piece of equipment, and it was a very successful prototype of the [Chem Plant] dissolvers.<sup>1</sup>*

The group patched the equipment together and began their experiments. The goal was to design a process for dissolving MTR fuel and extracting from it the substantial percentage of U-235 that had not fissioned during its seventeen days in the reactor. The huge expense of gaseous diffusion was invested in the fuel, so the effort to recover and recycle unused fuel was well justified.



Dissolver vessel for zirconium-alloyed fuels is in the foreground in this view inside a processing cell. The cells were entered rarely, and only after thorough decontamination.

The dissolver vessel was important. It had to contain the powerful acids that would dissolve sturdy metal alloys and not itself dissolve. Also it had to be small enough that the uranium inside it could not accidentally form a critical mass. Engineering was at least as important as the chemistry.

Dealing with the waste that the dissolution process would produce also occupied the group. They experimented with evaporators to reduce the volume of waste, much of which would be water. They articulated the principle of "holding the concentrate and discharging the condensate," a philosophy consistent with the AEC facilities' general approach to waste management—retaining high-level waste and dispersing low-level waste.

The group erected a pilot plant and after considerable experimentation, decided on the chemicals, the design of vessels and pipes, and the sequence of steps that would separate the uranium from the dissolved solution. They tested valves and instrumentation in a series of "cold run" tests using natural uranium and "warm runs" using low levels of irradiated uranium. Then they asked the AEC for five kilograms of irradiated U-235 from an Oak Ridge reactor.



Chem Plant technician demonstrates use of master-slave manipulator. Photographer entered hot cell before cell became "hot."

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*We were down in the cells one day when Miles Leverett brought in David Lilienthal, the chairman of the AEC. He looked around and said, "You are moving along pretty well." We said, "Yes, but we want to get five kilograms of U-235 irradiated, but we can't get it through the bureaucracy. He went back to Washington and three days later we had approval...*

*Somebody got the idea that if we could get this material irradiated in a Hanford production reactor where the flux was ten to fifty times higher than Oak Ridge's, we would get a bigger burn-up and a better demonstration. I made a trip to Hanford to look into this, but Hanford was not interested in doing outside irradiation. They had to*

*use all their neutrons for the production of plutonium. It was brought out that we were not asking for neutrons but giving them. They took a new look at it and pretty soon we had approval to go into the Hanford reactor.<sup>2</sup>*

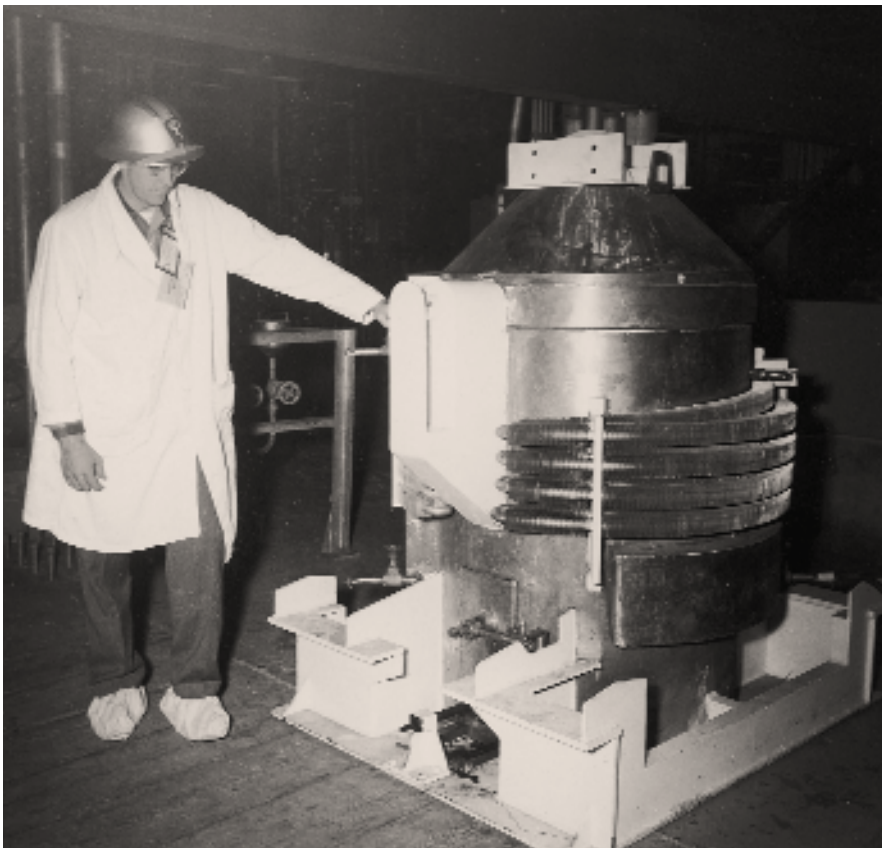
Upon seeding the reactor with enriched U-235 fuel elements, called slugs, Hanford happily discovered that the slugs helped increase the production of tritium. Tritium was a radioactive isotope of hydrogen used in bombs to boost the explosive power of the plutonium chain reaction. The AEC was building a reactor plant at Savannah River, South Carolina, to produce tritium, but until it was completed, the AEC was counting on Hanford. Thus it was decided that the Chem Plant, when

it was completed, would recover the unfissioned U-235 in the Hanford slugs.<sup>3</sup>

At AEC Headquarters, meanwhile, the staff concerned with weapons research was thinking about the Chem Plant in connection with an altogether different issue. It was trying to decide which of the AEC facilities should produce radioactive lanthanum-140, called RaLa for short, a material needed at Los Alamos for weapons experiments. Oak Ridge had been producing RaLa, but its equipment was hard to decontaminate, couldn't keep a predictable schedule, and was exposing workers to too much radiation. The bomb scientists at Los Alamos needed a more reliable source. The AEC had initially decided to build a new RaLa facility at Hanford, but with the MTR and the Chem Plant materializing in Idaho, they had another option to consider.<sup>4</sup>

RaLa is a fission product. After uranium atoms split and form (among others) isotopes of barium, the barium-140 isotope continues to decay into other isotopes, one of which is lanthanum-140. The problem with RaLa was that its mother isotope had a short half-life, and the half-life of RaLa also was short—about forty hours.

Spent MTR fuel fresh out of the reactor would contain RaLa. Up to this time, AEC Headquarters had not considered harvesting RaLa from the MTR. The plan was just the opposite. Spent nuclear fuel from the MTR would sit



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Shipping cask used to transport "green" MTR fuel elements. Note cooling coils.

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quietly in the storage canal for a few months just so that short-lived isotopes like RaLa could decay out of existence. After that, the fuel could go to the Chem Plant less hazardous to handle.

But the Korean War began in 1950. The AEC needed RaLa for weapons development. During World War II, scientists at Los Alamos had perfected the plutonium bomb as an implosion device. Explosive pressure from outside the small plutonium-239 core pushed the not-yet-critical mass into a critical mass. The bomb worked only if the sphere were compressed at the same instant from all sides. This was a problem solved with much trial and error and hundreds of (non-nuclear) test explosions. The experimenters used RaLa in test cores to help diagnose the efficacy of their gradually improving techniques. Work at Los Alamos now focused on creating thermonuclear weapons, and the scientists still required RaLa.<sup>5</sup>

Because RaLa decayed so quickly, the supplier and the user had to coordinate closely. When Los Alamos needed a quantity of RaLa for a pending experiment, it would inform Oak Ridge (or later, Idaho). Oak Ridge would remove fuel elements from a reactor, cool them a day or two, and drop them into a caustic bath. The caustic dissolved the cladding and the fuel, releasing the

Samples were drawn from all stages of the uranium extraction process and sent to the Remote Analytical Facility (until 1986). Here, technicians and scientists examined the hot samples to help determine the effectiveness of the process and ways to improve it.

### Support

In a typical office setting in the middle of a city, “support” means the administrative functions provided by the personnel, legal, accounting, payroll, and similar departments. In an industrial plant like the CPP, “support” meant a variety of laboratories with special equipment and functions.

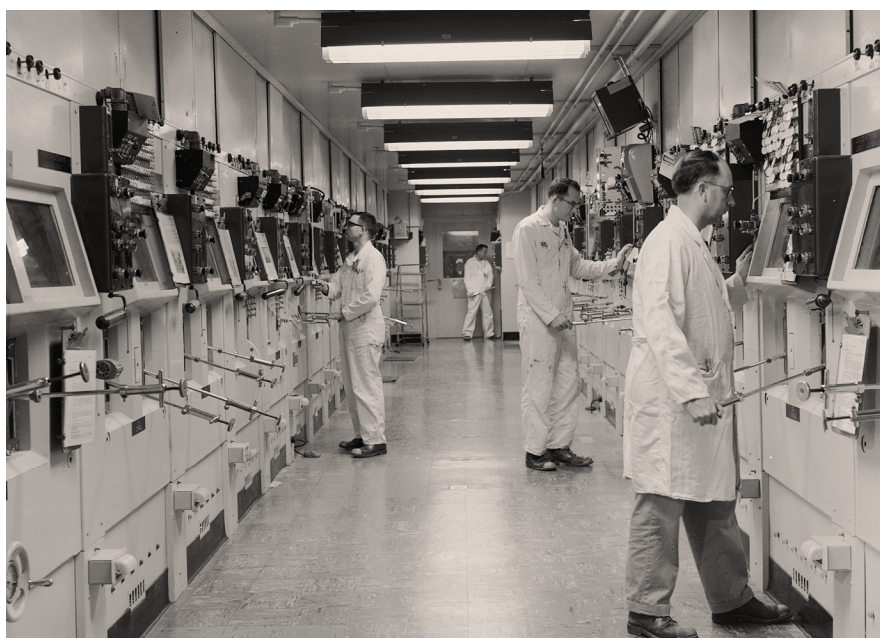
“Process” support meant working out ways to improve the chemical processes that are the main mission of the plant. This group designed bench-scale pilot experiments and tests to evaluate and compare with current practices.

“Analytical” support meant taking a sample of waste, water, or other substance and determining exactly what was in it and how much and what concentration. Laboratories were

loaded with X-ray equipment, shielded boxes, spectrometry, and chromatography instruments.

“Radiochemical” support could identify alpha, beta, and gamma-emitting radionuclides in any solid, liquid, or gas substance. People in these and other labs had to use alpha-tight containment cells and learn to use glove boxes and remote manipulators to protect themselves from radiation.

Another form of support peculiar to an environment with radioactivity came from safety specialists, who not only examined the accumulation of exposure on personnel badges, but evaluated techniques and procedures for safe operation of equipment and processes. They reviewed construction plans to see what the safety impacts would be when parts had to be repaired or replaced in case of an accident.



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lanthanum and (about 250) other fission products into the soup. The lanthanum was then recovered in a centrifuging process and shipped quickly to Los Alamos.

The dissolving process also liberated gases, among them radioactive iodine-131. The gas went through a filter and up a stack into the environment. It was the filtration system at Oak Ridge that was so ineffective. With a half-life of about eight days, iodine could settle onto blades of grass and eventually contaminate the milk of cows that ate the grass. Hanford's virtue, aside from its ready supply of fuel, was its isolation.<sup>6</sup>

Oak Ridge scientists persuaded AEC Headquarters that it would be more economical to produce RaLa in Idaho. They could add a RaLa capability to the Chem Plant for perhaps \$20 million less than building a plant at Hanford. The MTR could supply spent fuel every seventeen days. So it was done. The AEC assigned the RaLa operation to the Chem Plant, adding a small subsidiary defense mission to its original peaceful purpose.<sup>7</sup>

The Chem Plant might be thought of as a kitchen-in-reverse. Instead of putting ingredients together to make bread or cookies, the system was designed to begin with a finished product and recover only one of the original ingredients, say the sugar, and refine it so it could be used again. As in the case of RaLa, a secondary ingredient might also be retrieved. The rest of the ingredients and whatever chemicals it took to recover the prized ones would become wastes.

The Chem Plant removed the U-235 in a sequence of steps. Upon dissolving the fuel and its cladding in an acid, the next steps, called extraction cycles, introduced a chemical solvent that would form a compound only with the uranium. Then the compound was extracted and refined. Along the way, water was added to dilute the solutions to a composition suitable for extraction and to help prevent accidental criticalities. Later in the process, some of the water was evaporated. At first the solvent was hexone (methylisobutyl ketone), a chemical cousin of acetone (used in nailpolish remover). In 1955, the Chem Plant was modified and the extraction process improved with the use of tributyl phosphate in the first extraction cycle. Among other effects of this new process, the changes expanded the capacity of the plant.<sup>8</sup>

The Foster Wheeler Company designed the original plant. The Bechtel Corporation built it. The first operator, American Cyanamid, managed construction, hired operating personnel, and developed the first safety procedures and operating manuals. It took thirty-one months to build and cold-test the plant, making it ready for the first hot run. The designers had borrowed freely from existing technology, as Don Reid recalled.<sup>9</sup>

*Foster Wheeler...took the flow sheets developed by Oak Ridge and, using their oil refinery knowledge, converted these flow sheets to a commercial plant. Their nomenclature and drawings are still in use at ICPP. It was started in haste because it was a war plant—the Korean War was on...*

The Chem Plant in 1956 with Big Southern Butte to the south. The process building is at center right; the storage basins, at the southern edge of the complex.

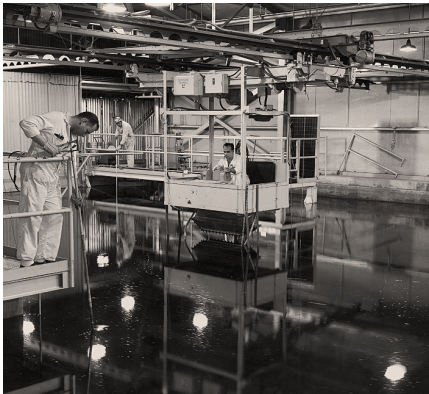


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*The plant construction started, but the design was done in New York City. It was a conglomeration of problems because most of the Foster Wheeler people were not security-cleared. We had to do everything unclassified, resulting in numerous trips back and forth between Oak Ridge, Washington, and New York.*

*...we had to use existing techniques and knowledge. The stack [design] was lifted right out of Hanford specifications and installed without change. The*



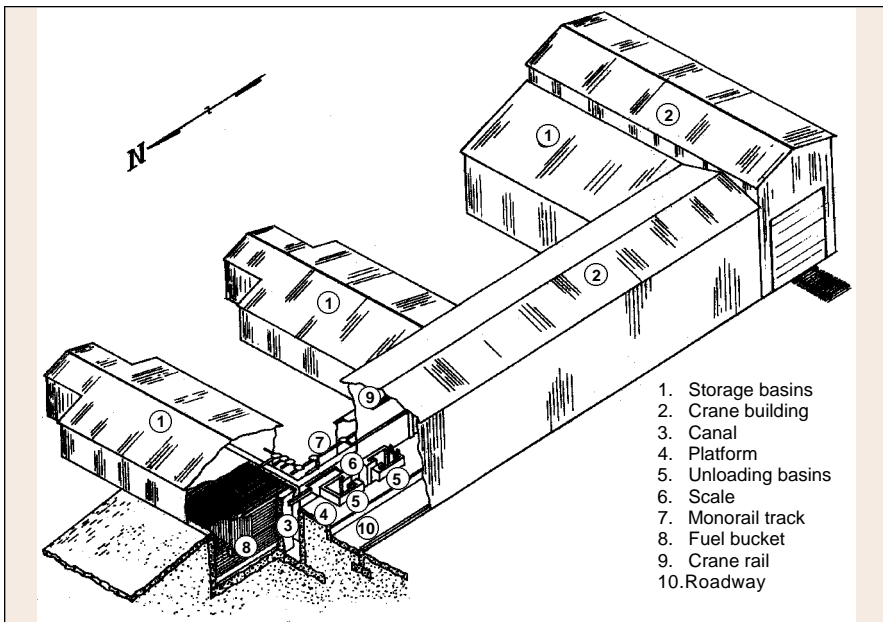
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*waste evaporator was a development at KAPL [Knolls Atomic Power Laboratory] for their waste evaporator and was just lifted in total and fabricated as such. The storage basin was a take-off from the storage basins at Hanford, even the buckets and monorail system. We bought an absolute duplicate of the original Hanford crane...The high priority of the CPP overrode all opposition.<sup>10</sup>*

The plant was expected to process fuels with different types of cladding—aluminum, zirconium, stainless steel. Each type called for a different process formula, and the fuels of different types could not be mixed. Therefore, the operators had to accumulate enough of each type to make it worthwhile to run a batch through. This meant that fuel arriving at the Chem Plant had to be stored someplace until enough had accumulated for a run.

So, part of the Chem Plant complex included a special fuel-storage building housing basins of water twenty feet deep. On the Chem Plant's 82-acre site, the basins were located about a third of a mile south of the main processing building. A year's accumulation of fuel was needed for the first production run, so the basin was finished first and opened for business while the rest of the plant was still under construction. The first shipment arrived in November 1951. Security was heavy. Said Reid, "None of the construction people could be allowed anywhere near the vicinity." One of the first security guards at the Chem Plant was Mark L. Sutton (later an Operator Helper), who recalled:

*I was often assigned to the ICPP area for patrol and exit/entry control at the guard house or gates. The whole ICPP area seemed to be a maze of pipe trenches, cement pours, worker's tools and office shacks. The [fuel storage building] was perhaps already complete and had some Hanford "J" slug fuel elements stored under water in it, but at that time I was not acquainted with the intended activities and the terms describing them.<sup>11</sup>*



Above. Storage pool at the Fuel Storage Building. At center is a transfer crane with a riding cab. The fuel is stored in cadmium-lined racks under 20 feet of water. Left. Schematic view shows unloading pools, canal, and other features of the Fuel Storage Building.

## Memories of an Operator Helper at the Chem Plant

I recall reporting to Shift Supervisor Archie Larson on a Sunday day shift. He gave me an orientation in the works of the Process Makeup area, where non-radioactive chemicals were measured and mixed for use...

...Operator Helpers were shown how to air sparge [agitate a liquid by pumping air into it] solutions in vessels so as to mix the chemicals into a homogeneous solution, and then where and how to draw samples and to take them to the Shift Lab for analysis. This work was considered entry-level, and training was “on the job,” usually by experienced helpers and/or Operators. Experienced personnel were most always anxious to be relieved of this type of work because of the tedium [and] ever-present risk of radioactive contamination—analogue to “dirty work.”

One other usual job for Operator Helpers was to mop up radioactive materials when they were inadvertently released from the intended confines of the process piping, vessels, sample garages, sample bottles, and cell vent systems. There was a sort of unwritten code that whoever caused a “spill” or release of radioactive material, thus creating radioactive contamination of an area, should be the one to clean it

up. This, often as not, fell to the lowly Helper because he was the one delegated to do that “dirty radioactive sampling” work, but whenever the Helper could pin the cause on an Operator, he did get some help.



Water and mopheads were basic aids for decontaminating spills.

...I was also assigned [to] the Waste Processing building. This work, of course, included the usual sampling, mopping, and routine shift readings. Waste collection was an on-going continuous operation, if not the surveillance of filling vessels or pump-outs, then periodically the operation of the low-level liquid waste evaporator...with the attendant collection of “clean” non-radioactive condensate...and disposal to the service waste well—or re-run, if it

was not within specifications as ascertained from the samples submitted by the Helper to the Shift Lab.

Most plant work was done on a 24-hour day coverage by three crews working eight-hour shifts... [rotating shift work was less desirable than straight day work but better than [straight evening or straight midnight shifts].

I also worked as an Operator Helper on an aluminum-clad radioactive fuel element processing campaign...I helped charge fuel elements to the dissolvers for batch-wise dissolution, pulled input feed samples, helped with routine readings, and made some of the acid or base feed adjustment additions...

Vessels, pumps, etc, in each cell or Process Makeup area were titled/labeled with those respective area designations and followed by three-digit numbers, the first digit...designating the type of equipment as follows: 1-vessel, 2-pump, 3-heat exchanger, 4-agitator, 5-jet, 6-sampler, 7-burette, 8-funnel, 9-special. Thus C-101 was a vessel in C Cell, D-301 was a heat exchanger in D Cell.

Mark L. Sutton

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Cask-heavy trucks rumbled past the security gate at the Chem Plant's west fence and disappeared into special entry bays at the storage building. Cranes removed the casks from the trucks and deposited them underwater, where mechanical hands removed the fuel and placed it into stainless-steel buckets suspended from overhead tracks. The fuel moved along to its assigned resting space. The shielding water carried away heat and was recirculated and refreshed daily, the overflow injected to a disposal well just south of the building. To the water had been added chlorine to prevent the growth of algae. Sodium nitrate was added to prevent the chloride from dissolving the stainless-steel cladding or accelerating the corrosion of the aluminum cladding. The building had its own motor generator set for an emergency power supply.<sup>12</sup>

In February 1953 the operators were ready for their first hot run. They had test-run the plant using non-irradiated uranium, and by trial and error, calibrated all of the instrumentation. They had checked out the plant's fifty-plus miles of piping and tubing. Using magnets and nitric acid, they made sure all the pipe fittings were made of stainless steel. Despite previous inspections and controls, they found a few fittings made of the wrong material, and the pipe fitters had to cut them out and replace them.<sup>13</sup>

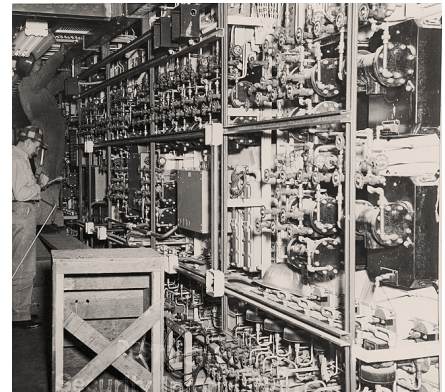
After the AEC decided to equip the Chem Plant with a RaLa facility, military officers arrived on the scene to help expedite procurement and otherwise remove barriers to early completion. They proposed that government



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employees run the plant instead of contractors. Despite the country's wartime footing, the AEC rejected the idea because the recycling of uranium was intended eventually to be a component of the commercial power industry, and civilian companies would have to learn how to do it. Besides, contractors had a good war record, having produced the atom bomb.<sup>14</sup>

American Cyanamid thus recruited engineers, chemists, and mechanics from industries all over the United States. The recruits went to a special school at Oak Ridge to learn basic nuclear technology and how to handle radioactive material. Arriving in Idaho in 1951 with the plant still under construction, they set up their first offices at the Central Facilities Area in the Navy's handy white houses. They prepared to train others, writing safety manuals, operating procedures, and process specifications. Someone decided the Chem Plant would use the metric system, which was somewhat unusual



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Above. Shipping cask arrives at the CPP. Below. Pneumatic instrument tubing is installed behind the facade of the operating corridor where operators will control process.

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for American chemical companies at the time, so that became part of the training, too.<sup>15</sup>

Straddle-carriers, long-legged transporters adapted from timber industry lumber-handlers, brought casks loaded with the first fuel elements from the storage basin to the head end of the process building, where fuel was dropped remotely into the dissolver in the first cell. Remotely operated cutters at the basin had trimmed as much structural metal from the fuel as practical before the fuel headed down the chute into the dissolver vessel.

The work with the highly radioactive material was mostly below ground level, so that the earth formed part of the shielding. Each vessel was isolated in its own shielded room, or cell, typically about twenty feet square. During a run,

operators stood attentively in an operating corridor between the banks of cells, facing gauges and other instruments, their hands on levers that would open or shut pertinent valves by remote control, heat up certain solutions and cool down others. Pumps, steam jets, or airlifts advanced the feed from one vessel to the next. The pipes penetrated the dense concrete walls, five feet thick around each cell. Piping also brought the water, air, or chemical additives to the cells from upper-level storage tanks. Certain reactions produced gases, and pipes carried it away. Each of the original twenty-four cells had a name, beginning with A Cell and proceeding through the alphabet (skipping I and O). As the Chem Plant opened, several spare cells awaited future developments.<sup>16</sup>

The first run dissolved Hanford slugs. It lasted six months and recovered over

240 kilograms of U-235 in the form of uranyl nitrate, a thin yellow liquid. The Chem Plant shipped it unshielded to Oak Ridge, although it was packaged in ten-liter stainless-steel bottles encased in a “birdcage” framework designed to prevent accidental criticalities.<sup>17</sup>

The liquid waste, of course, remained at the Chem Plant. As in so many other corners of the NRTS, this was one more place where scientists and engineers could say they were doing something new. Pipes conveyed the waste underground into a 300,000-gallon stainless-steel storage tank (nested within a concrete vault) east of the process building. Stainless steel had become more available after World War II. Hanford had used carbon steel, having no other choice, and then neutralized its acidic waste with caustic. This increased its volume, caused solids to form a sludge,



INEEL 57-112

Chemist Bernice Paige was the first woman to win a lifetime achievement award from the American Nuclear Society for her technical contributions to nuclear science.



INEEL 06940

Lowering slug charger over the slug chute above a dissolver.



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November 1952. CPP operators transfer a filled bottle of concentrated uranyl nitrate product into a “bird cage” for shipment to Oak Ridge.

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and made future retrieval hazardous and costly. The Chem Plant spared itself from these particular problems, perhaps because its research mission generated different decisions. The stainless steel tanks allowed the storage of waste in acidic form and resisted corrosion. Scientists assumed that disposal to the environment was "out of the question," that tanks were not the final resting place for the waste, that isotopes in the waste might have further use and should be retrievable, and that nothing should preclude the option of transforming the liquid into a safer, more stable, solid form.<sup>18</sup>

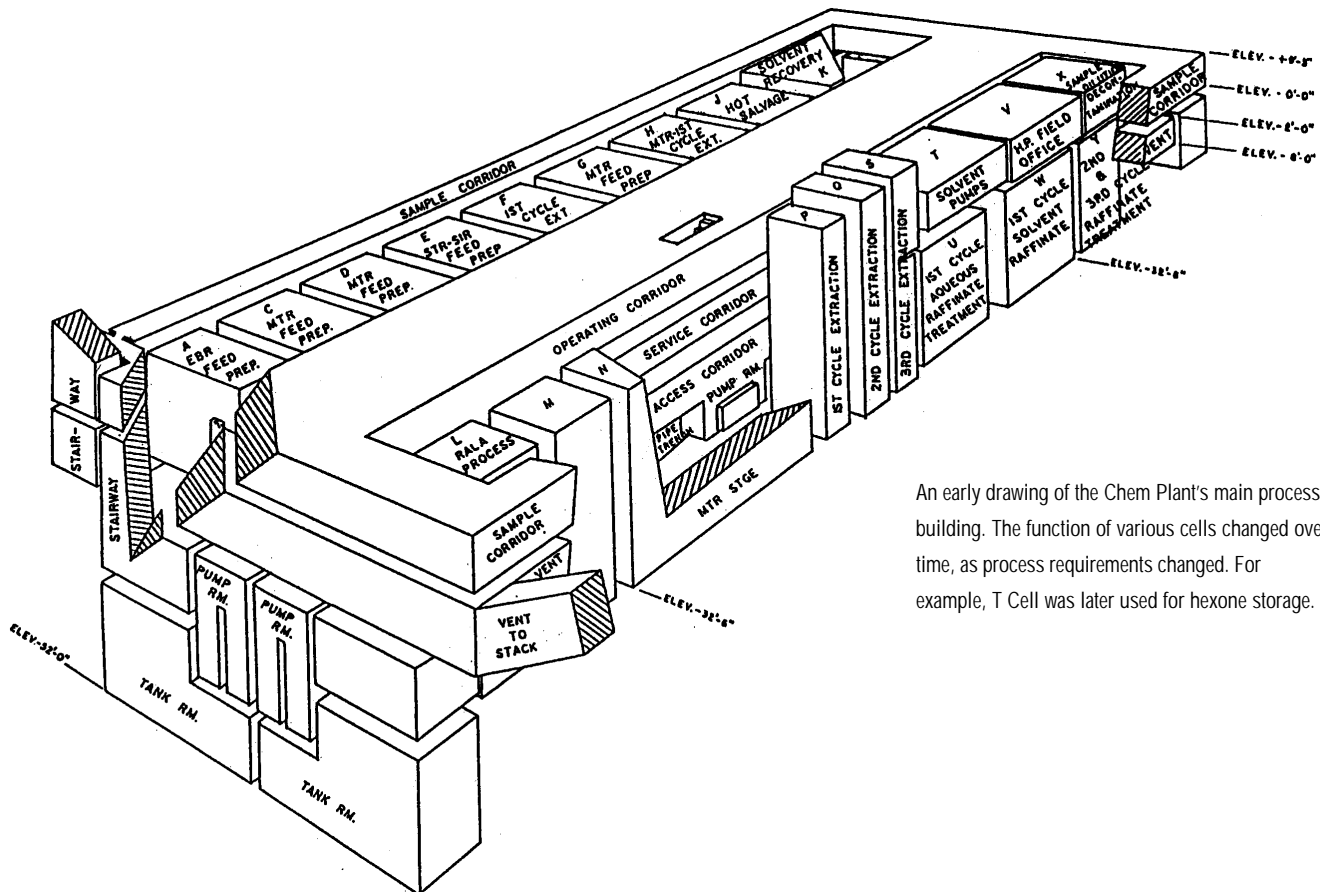
When the run was over, the operating crew decontaminated cells, vessels, and pipes and prepared for the second run, slated for MTR fuel. The plant was partly an experiment in direct maintenance

with stainless steel. Then crews entered the cells from the access corridor to repair valves and other fixtures *via* direct physical contact. For the benefit of future commercial plants, the AEC hoped to demonstrate that this method could potentially reduce operating costs and not overexpose employees.<sup>19</sup>

Subsequent runs filled the first storage tank with liquid waste. Ten more were built; one of them always stood empty in case of a leak. Operators could transfer the liquid either from a leaking tank or the concrete vault into which the liquid had accumulated. When full, each tank contained only a few gallons of pure radioactive fission products. The rest of the solution was dissolved cladding-metal ions, process additives, and water. The tanks

first cycle extraction, which accumulated most of the fission products, had cooling systems to carry away decay heat to minimize corrosion. Other liquid wastes included condensate (containing low levels of radioactivity), and those went into a disposal well.<sup>20</sup>

The Chem Plant was launched. Over time, the plant recovered U-235 from many new types of fuel. Each had unique cladding and fuel chemistry, challenging the chemists and engineers to develop new formulas in small-scale pilot plant workshops, most of which also required modifications in the physical plant. Process development became a regular Chem Plant activity.<sup>21</sup>



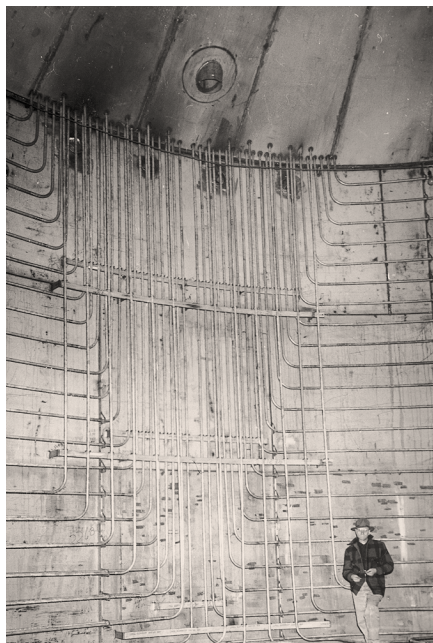
An early drawing of the Chem Plant's main process building. The function of various cells changed over time, as process requirements changed. For example, T Cell was later used for hexone storage.

## PROVING THE PRINCIPLE

Sometimes the task seemed deceptively simple, such as a request later in the 1950s to process spent fuel from Savannah River reactors. The fourteen-foot-long elements were clad in alu-

minum and had to be cut to eighteen-inch lengths to fit into the dissolver vessel. The engineers practiced the cutting procedures with non-irradiated elements and built a special cutting machine to do the job. As they began preparing for the hot run, said Don Reid,

*...we soon found out that we had exceeded the technical knowledge of the materials. We found that the Savannah tubes, while being irradiated, had changed metallurgical characteristics. Instead of cutting like regular aluminum—on which the cutters had been tested—they crumbled like graham crackers, so a whole new technique and procedure had to be developed. Maintenance was extremely difficult because of the crumbling, and a very extensive complete modification [of the process was] required.<sup>22</sup>*



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But the requisite persistence and ingenuity were available, and the Chem Plant crew eventually conducted another successful run. Such accomplishments helped move the Chem Plant beyond its original mission to recover just two or three types of fuel. It became a permanent fixture—and a revenue generator—at the NRTS. The plant processed at least a hundred varieties of spent nuclear fuel. It came from university and test reactors all over the world, from commercial power plants, from most of the reactors at the NRTS, and from Navy ships.

The RaLa program lasted from 1956 to 1963, the province of the complicated L Cell, which had a remote viewing window and several miles of piping. In the early days, each time green MTR fuel clattered into the vessel to be dissolved in acid, a puff of radioactive iodine blew out the Chem Plant stack. The way to control a release was to time it in concert with benign weather conditions. Managers evacuated outdoor construction workers who might be around the area. The IDO Health and Safety Branch required that iodine releases occur only when the weather—wind direction and speed—fit a certain profile to promote dilution and movement towards unpopulated areas. Later, activated charcoal scrubbers absorbed iodine, and a special tank was installed to retain the gas for later release.<sup>23</sup>

Above. Cooling pipes inside 300,000-gallon waste tank. Left. "Pillar and panel" vault under construction in 1955 for one of the Chem Plant's eleven 300,000-gallon waste tanks. Concrete components were precast.

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Monitoring the iodine releases to make sure operating contractors kept within IDO-set guidelines was the task of health physicists. Monitoring teams carried radiation detectors and patrolled site roads and the public highway near Mud Lake during a release. When their meters detected a radioactive cloud, they took the highest reading and collected air samples. They collected jack rabbits and analyzed their thyroids, often finding these to be better indicators of off-site exposure to iodine than were their meters. Of course, collecting the jack rabbits also required special techniques, as HP John Byrom recalled later:

*One method used was with a seat anchored to the front fender of a truck and a gunner with a shotgun strapped to the seat...The driver would head out across the sagebrush until the rabbit was flushed. Then it was up to the gunner to harvest the bunny. Much powder was probably burned before the gunners got very good at this sport. Talks with the gunners indicated it was... rather hard on the seat of understanding. All in all, the method was quite successful and many specimens were collected, whether in self-protection or skill I could never learn.<sup>24</sup>*

The march of progress eventually made bunny gunners obsolete. Like much else at the Site, pioneering methods gave way to more economical or more effective improvements. To detect the iodine cloud as it exited the Chem Plant stack, for example, someone devised a "scintillation sky scanner." The device used a pivoting gun barrel as a shield. It was erected just outside the Chem Plant fence and trained on the top of the

stack. The RaLa operators were in radio contact with an HP at the scanner. "We dropped it!" they would say. The scanner detected the iodine cloud the moment it exited the stack. This device was also responsible for revealing that the stack released iodine while process vessels inside L Cell were being decontaminated. Learning this, the RaLa operators changed the decontamination schedule, doing it just before the next run, giving the iodine more time to decay.<sup>26</sup>

Iodine-131 (I-131) was potentially the most hazardous of the isotopes released to the atmosphere by any of the operations at the NRTS, and the RaLa program was the major contributor. However, the releases were not a secret. When the IDO began distributing quarterly environmental reports in 1959, the reports identified the curies of iodine released by these runs and maximum levels that had been observed.<sup>26</sup>

None of the iodine releases at the Chem Plant (or anywhere else at the NRTS) crossed the boundaries of the Site exceeding the radiation protection standards applicable at the time. In the RaLa days, the highest dose to drift off-site may have been nine percent of the allowable concentration.<sup>27</sup>